Interim Geologic Map of the Kolob Arch Quadrangle,
Washington and Iron Counties, Utah

By

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KOLOB ARCH QUADRANGLE

Map Unit Descriptions

QUATERNARY

Alluvial deposits

Qal_1 **Stream deposits** (Holocene) – Moderately to well-sorted sand, silt, clay, and pebble to boulder gravel in river channels and flood plains; locally includes small alluvial-fan and colluvial deposits, and minor terraces up to 10 feet (3 m) above current base level. Generally 0 to 20 feet (0-6 m) thick, although deposits west of Ash Creek Reservoir are likely thicker.

Qat_{2-3} **Stream-terrace deposits** (Holocene and upper Pleistocene) – Stratified, moderately to well-sorted sand, silt, and pebble to boulder gravel that forms level to gently sloping terraces above modern drainages. Because incision rates vary across the Hurricane fault and also likely upstream along major drainages, age equivalency of Qat_2 and Qat_3 deposits across the quadrangle is not known. Subscript thus denotes only height above active drainages: level 2 deposits are 10 to 30 feet (3-9 m) and level 3 deposits are 30 to 90 feet (9-27 m) above modern drainages. Deposited in river-channel and flood-plain environments; may include colluvial and alluvial-fan deposits too small to map separately. 0 to 30 feet (0-9 m) thick.

Qao **Older stream deposits** (middle to upper Pleistocene) – Moderately sorted sand, silt, and pebble to boulder gravel that forms isolated deposits high above Taylor and LaVerkin Creeks. Prominent clasts include gray limestone from the Carmel Formation, some of which contain *Pentacrinus* sp. crinoid columnals and pelecypods; yellowish-brown, iron-stained Cretaceous

sandstone; reddish-brown to reddish-orange sandstone from the Kayenta and Navajo Formations; and basalt. Taylor Creek deposits also contain clasts derived from the Chinle and Moenkopi Formations. Taylor Creek deposits lie up to about 170 feet (52 m), and LaVerkin Creek deposits up to 250 feet (76 m), above adjacent drainages. Deposited in river-channel environment. 0 to 30 feet (0-9 m) thick.

Qas **Alluvial sand deposits** (upper Holocene) – Well-sorted, fine- to medium-grained sand weathered from the Navajo Sandstone and re-deposited in narrow washes. Forms planar surfaces, entrenched by intermittent streams, in the southeast corner of the quadrangle. Also mapped on the floor of Hop Valley, where the Hop Valley stream has reworked the upper few feet of sandy lacustrine and basin-fill deposits. 0 to about 25 feet (0-8 m) thick, but only a few feet thick in Hop Valley.

Qaf_1, Qaf_2

Alluvial-fan deposits (Holocene to upper Pleistocene) **–** Poorly to moderately sorted, non-stratified, boulder- to clay-size sediment deposited as small discrete alluvial fans along major drainages. Level 1 deposits form active depositional surfaces, although locally the master stream is deeply entrenched; level 2 deposits form deeply incised surface up to 100 feet (30 m) above active drainages and are truncated at the downstream end by stream deposits (Qal_1) or mixed alluvial and colluvial deposits (Qac). Typically overlies alluvial channel deposits at the toe of the fans, and may include minor slopewash and talus along the upslope margins of the fans. Generally 0 to 40 feet (0-12 m) thick.

Qafy **Younger coalesced alluvial-fan deposits** (Holocene to Pleistocene) – Poorly to moderately sorted, non-stratified, boulder- to clay-size sediment deposited as broad, coalescing alluvial fans in the New Harmony basin west of the Hurricane Cliffs. Deposited principally by debris flows issuing from drainages that cross the Hurricane Cliffs. Forms active depositional surface adjacent to the Hurricane Cliffs, but major formative streams, including Taylor, Kanarra, and Ash Creeks, are deeply incised along the lower portions of the fans. Gradational with talus (Qmt) deposits at the base of the Hurricane Cliffs. Well-developed debris-flow levies are locally present on the upper portions of the fans. The thickness of Quaternary basin-fill deposits (Qafy and Qafo) west of the Hurricane Cliffs in the Kolob Arch qudrangle is not well constrained; Hurlow (1998) estimated that they may be about 2,000 feet (610 m) thick.

Qafo **Older coalesced alluvial-fan deposits** (Pleistocene) – Similar to Qafy deposits, but deeply incised and with moderately developed pedogenic carbonate. Forms deeply incised surface up to about 100 feet (30 m) above active drainages in the west-central part of the quadrangle. May be exposed west of Hurricane Cliffs due to relative uplift along unrecognized and unmapped normal fault(s) near the west edge of the quadrangle. Older alluvial-fan deposits are also preserved on the Hurricane Cliffs just north and south of Pace Knoll, where they consist of poorly to moderately sorted, non-stratified, boulder- to clay-size sediment; there, clasts consist principally of subangular upper Moenkopi and Shinarump strata and basalt and the unit is 0 to about 30 feet (0-9 m) thick.

Artificial deposits

Qf **Artificial fill** (Historical) – Engineered fill used to create roadbeds and dams. Although only the larger, thicker deposits are mapped, fill should be anticipated in all developed areas, many of which are shown on the topographic base map. Thickness variable.

Qfm **Mine-dump deposits** (Historical) – Waste rock from uranium mining near the Kolob Canyons Visitors Center. 0 to about 20 feet (0-6 m) thick.

Colluvial deposits

Qc, Qco

Colluvial deposits (Holocene to Pleistocene) **–** Poorly sorted, angular, clay- to boulder-size, locally derived sediment deposited principally by slopewash and soil creep; locally includes talus, alluvial, and eolian deposits too small to map separately. Gradational with talus deposits. Older colluvial deposits (Qco) mapped along Taylor Creek and on the Kolob Plateau in the northeast corner of the quadrangle form deeply dissected surfaces. Qco deposits on the Kolob Plateau cap ridge crests and consist principally of reworked Dakota strata. Qc deposits are generally less than 20 feet (6 m) thick; Qco deposits are 0 to 100 feet (0-30 m) thick.

Eolian deposits

Qes **Eolian sand deposits** (Holocene) – Well- to very well-sorted, fine- to medium-grained, well-rounded, frosted quartz sand derived from the Navajo Sandstone. Mapped only on top of the Hop Valley landslide and at Neagle Ridge where it partly fills irregular depressions. 0 to 20

feet (0-6 m) thick.

Lacustrine and basin-fill deposits

Qla **Lacustrine and basin-fill deposits** (Holocene) – Well-stratified sand, silt, and lesser clay deposited in small lakes or basins created by landslides. Typically grades into colluvial, alluvial, and alluvial-fan deposits at basin margins. Forms planar surfaces that slope downstream, and, except for the Beatty Lake deposits, all are incised by streams once blocked by mass movements. A radiocarbon age of 2,640 ± 60 yr B.P. establishes a minimum age for the formation of Hop Valley Lake, and Eardley (1966) obtained a radiocarbon age of 670 ± 200 yr B.P. from the upper part of the deposits; deposits in Hop Valley could be as much as 350 feet (107 m) thick. Paria Lake deposits are up to about 30 feet (9 m) thick; the lake existed from about 3,900 ± 60 yr B.P. to 2,880 ± 200 yr B.P. (Eardley, 1966; Hamilton, 1995). Two radiocarbon ages of 2,900 ± 70 yr B.P. and 630 ± 40 yr B.P. establish the duration of Current Creek Lake; nearby Cane Creek Lake deposits are likely of a similar age. Beatty Lake deposits may be up to 200 feet (61 m) thick; the age of lake formation is not known, but is likely less than 2,000 to 3,000 years old.

Mass-movement deposits

Qmsh, Qmsy, Qmso

Landslide deposits (Historical to Pleistocene) **–** Very poorly sorted, clay- to boulder-size, locally derived material deposited principally by rotational slides; includes large, collapsed wall of Navajo Sandstone that blocks Hop Valley. Characterized by hummocky topography, numerous internal scarps, and chaotic bedding attitudes. Basal slip surfaces most commonly

form in Petrified Forest, Shnabkaib, middle and upper red, Kayenta, and Crystal Creek strata, as well as talus; the slides themselves incorporate these and overlying map units. Qmsh denotes slides with historical movement; younger landslides (Qmsy) may have historical movement, but typically are characterized by slightly more subdued landslide features indicative of early Holocene to late Pleistocene age. Older landslides (Qmso) are deeply incised and their head scarps and hummocky topography have been extensively modified by erosion; they are likely late Pleistocene in age. Thickness highly variable.

Qmt **Talus deposits** (Holocene to upper Pleistocene) – Very poorly sorted, angular boulders and finer-grained interstitial sediment deposited principally by rock fall on and at the base of steep slopes. Typically grades downslope into colluvial deposits, and may include colluvial deposits where impractical to differentiate the two. Generally less than 30 feet (10 m) thick, although deposits on the Hurricane Cliffs in the southwest corner of the quadrangle are likely thicker.

Mixed-environment deposits

Qac

Alluvial and colluvial deposits (Holocene to upper Pleistocene) **–** Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediments deposited principally in swales, small drainages, and the upper reaches of larger streams by fluvial, slopewash, and creep processes; gradational with both alluvial and colluvial deposits. Generally less than 20 feet (6 m) thick.

Qea **Eolian and alluvial deposits** (Holocene to Pleistocene) – Well-sorted, fine- to medium-grained, reddish-brown eolian sand reworked by alluvial processes. Mapped south of Ash Creek Reservoir where it locally conceals the Pintura flow. 0 to 20 feet (0-6 m) thick.

Qeac **Eolian, alluvial, and colluvial deposits** (Holocene to Pleistocene) – Similar to mixed eolian and alluvial deposits (Qea) but with a significant amount of basalt colluvium shed from adjacent slopes. Mapped south of Ash Creek Reservoir where it locally conceals the Pintura flow. 0 to 20 feet (0-6 m) thick.

Volcanic rocks

Qbg **Grapevine Wash flows** (middle Pleistocene) – Medium-gray, weathering to dark-brownish-gray to dark-brownish-black, fine-grained olivine basaltic trachyandesite. Five $^{40}Ar/^{39}Ar$ ages on these flows range from 0.22 $\pm$ 0.03 Ma to 0.31 $\pm$ 0.02 Ma. Erupted from a number of vents on the Lower Kolob Plateau, including the Firepit Knoll and Spendlove Knoll cinder cones. Only distal end of one flow is preserved at the south end of Hop Valley, where it is about 20 feet (6 m) thick.

Qbp, Qbpc

Pintura flow and cinder cone (lower Pleistocene) – Medium- to dark-gray, fine- to medium-grained olivine basalt or trachybasalt with, in some flows, plagioclase phenocrysts. Forms resistant cap of Pace Knoll and Black Ridge, and covers the hanging wall of the Hurricane fault in the southwest corner of the quadrangle. Yielded five $^{40}Ar/^{39}Ar$ ages of 0.89 $\pm$ 0.02 Ma, 0.81 $\pm$ 0.10 Ma, 0.87 $\pm$ 0.04 Ma, 0.88 $\pm$ 0.05 Ma, and 0.84 $\pm$ 0.03 Ma, (Lund and others,

2001; Biek, in preparation); these last two ages are from the Kolob Arch quadrangle, from Ash Creek (SE1/4SE1/4SE1/4 section 7, T. 39 S., R. 12 W.) and the north end of Black Ridge (NW1/4NW1/4NW1/4 section 16, T. 39 S, R. 12 W.), respectively. Flows are generally 10 to 30 feet (3-9 m) thick, but thicken where they fill paleodrainages; a stacked series of about 12 flows is 780 feet (238 m) thick on Black Ridge immediately north of the southern boundary of the quadrangle. Qbpc indicates cinder cone at southwest corner of quadrangle, likely the principal source of the flows; cinders are also mapped near Ash Creek Reservoir.

Qbhr **Horse Ranch Mountain flow** (lower Pleistocene) – Medium-gray, fine- to medium-grained olivine basalt. Where the flow caps Horse Ranch Mountain, it is underlain by about 50 feet (15 m) of poorly exposed, unmapped, rubbly, vesicular basalt. Yielded an $^{40}Ar/^{39}Ar$ age of 1.03 $\pm$ 0.06 Ma. A single cooling unit about 30 feet (10 m) thick caps the northeast end of Horse Ranch Mountain, whereas the westernmost basalt exposure in section 23 contains at least seven cooling units that total about 125 feet (38 m) thick; vesicle alignment and paleotopography show that the basalt flowed generally from east to west; the source of the flow is unknown.

unconformity

TERTIARY

Taf **Old alluvial-fan deposits** (Miocene to Pliocene) – Deeply dissected, poorly to moderately consolidated, boulder- to clay-size sediment. Prominent clasts include Miocene volcanic and plutonic rocks and Tertiary to Late Paleozoic sedimentary rocks, which are exposed to the

west and northwest. Mapped on the southeast flank of the Harmony Mountains in the northwest corner of the quadrangle, where Hurlow (1998) noted it dips about 15 degrees east. Deposited principally by debris flows. Hurlow (1998) described three informal units; only the upper few hundred feet of the upper member is exposed in the quadrangle, but the upper member is about 700 feet (213 m) thick in the Harmony Mountains.

unconformity

Tip **Quartz monzonite porphyry** (Miocene) – Grayish-pink-weathering quartz monzonite porphyry. Deeply weathered to gruss-like soils. Exposed in fault blocks at the base of the Hurricane Cliffs. The maximum exposed thickness is about 115 feet (35 m).

unconformity

Tc **Claron Formation** (Paleocene to Eocene) – Thin- to medium-bedded, orangish-red, reddish-brown, and yellowish-brown, calcareous silty sandstone and siltstone. Forms highly fractured fault blocks at the base of the Hurricane Cliffs, where it weathers to poorly exposed but brightly colored slopes. Thickness uncertain, but possibly up to 300 feet (91 m) thick.

unconformity

CRETACEOUS

Cedar Mountain Formation

Kcmc **Conglomerate member** – Very poorly exposed at Horse Ranch Mountain; the following description is based largely on exposures in the adjacent Kolob Reservoir quadrangle. Thick- to very thick-bedded, yellowish-brown, channel-form conglomerate, pebbly sandstone, and pebbly gritstone. Clasts are subrounded to rounded, pebble- to small-cobble-size quartzite, chert, limestone, and rare, reworked petrified wood. Locally stained reddish-brown to dark-yellowish-brown. Discernable at Horse Ranch Mountain due to quartzite and chert pebbles weathering out and accumulating on the surface; colluvium below the conglomerate horizon contains angular, cobble- to boulder-size Dakota-like sandstone blocks, suggesting that several feet of Dakota strata may be concealed above the conglomerate. Deposited in river-channel environment on a broad lowland. Biek and Hylland (in press) reported a single-crystal $^{40}Ar/^{39}Ar$ age of 97.9 $\pm$ 0.5 Ma on sanadine from a volcanic ash in mudstone immediately above this conglomerate bed in the Straight Canyon quadrangle to the east; recent pollen analyses also indicate an Albian or older age for these beds. Probably 20 to 25 feet (6-8 m) thick at Horse Ranch Mountain.

unconformity (K)

JURASSIC

Carmel Formation

Jcw **Winsor Member** – Light-reddish-brown, very fine- to medium-grained sandstone and siltstone. Poorly cemented and so weathers to densely vegetated slopes, locally with badland topography. Upper contact is the Cretaceous unconformity; at Horse Ranch Mountain, Winsor strata are overlain by the very poorly exposed conglomerate member of the Cedar

Mountain Formation. Deposited on a broad, sandy mudflat. About 320 feet (98 m) thick.

Jcp **Paria River Member** – Laminated to very thin-bedded, light-gray argillaceous limestone and micritic limestone that overlies a thick, white, alabaster gypsum bed. Limestone weathers to small chips and plates; forms steep, ledgy slopes; and locally contains small pelecypod fossils. Upper contact is sharp and planar. Deposited in shallow-marine and coastal-sabkha environments. About 125 feet (38 m) thick.

Jcx **Crystal Creek Member** – Thin- to medium-bedded, reddish-brown gypsiferous siltstone, mudstone, and very fine- to medium-grained sandstone. Typically friable and weakly cemented with gypsum. Forms vegetated, poorly exposed slopes. Upper contact is sharp and broadly wavy and corresponds to the base of a thick Paria River gypsum bed. Deposited in coastal-sabkha and tidal-flat environments. About 250 feet (76 m) thick.

Co-op Creek Limestone Member – Thin- to medium-bedded, light-gray micritic limestone and calcareous shale. Locally contains *Pentacrinus* sp. columnals, pelecypods, and gastropods. Deposited in a shallow-marine environment.

Jccu – **Upper unit** of thin- to medium-bedded, light-gray-weathering micritic limestone; locally oolitic and sandy. Forms sparsely vegetated, ledgy slopes and cliffs. Upper contact is sharp and planar. About 140 to 200 feet (43-61 m) thick.

Jccl – **Lower unit** of mostly thinly laminated to thin-bedded, light-gray-weathering

calcareous shale and platy limestone. Forms steep, vegetated slopes. Contact with upper unit is gradational and corresponds to a subtle break in slope and vegetation patterns. About 380 feet (116 m) thick.

unconformity (J-2)

Temple Cap Formation

Jts **Sinawava Member** – Interbedded, slope-forming, moderate-reddish-brown mudstone, siltstone, and very fine-grained silty sandstone. Forms narrow, but prominent, deep-reddish-brown, vegetated slope at the top of the Navajo Sandstone. Upper, unconformable contact is poorly exposed, but corresponds to the base of light-gray calcareous shale and micritic limestone. Deposited in coastal-sabkha and tidal-flat environments. About 10 feet (3 m) thick.

unconformity (J-1)

Jn **Navajo Sandstone** – Moderate-reddish-orange to moderate-orange-pink, massively cross-bedded, poorly to moderately well-cemented, well-rounded, fine- to medium-grained, frosted quartz sandstone. Contains a few planar interdune deposits. Forms spectacular, sheer cliffs and is locally prominently jointed. Upper, unconformable contact is sharp and planar and corresponds to a prominent break in slope, with cliff-forming, cross-bedded sandstone below and reddish-brown mudstone above. Deposited in a vast coastal and inland dune field with prevailing winds principally

from the north; the lower few hundred feet represents deposition in a sand-dominated sabkha environment. About 2,100 to 2,200 feet (640-670 m) thick.

Jmk(s) **Slide blocks of Moenave and Kayenta Formations, undivided** – Moenave and Kayenta strata exposed along the Taylor Creek thrust fault zone west of Timber and LaVerkin Creeks and south of Shuntavi Butte. Generally highly brecciated and fractured, although a ledge of Springdale Sandstone is present on the east flank of Black Ridge.

Jk **Kayenta Formation** – Interbedded, thin- to very thick-bedded, moderate-reddish-brown siltstone, fine-grained sandstone, and mudstone with planar, low-angle, and ripple cross-stratification; contains several thin, light-olive-gray weathering, light-gray dolomite beds. Lower part generally weathers to poorly exposed slopes, upper part to ledges and small cliffs. Upper contact is conformable and gradational and corresponds to the top of the highest thin siltstone and mudstone beds, above which lie the towering cliffs of Navajo Sandstone; throughout much of the Kolob Canyons area, the contact is at the base of a white-weathering sandstone bed. Deposited in fluvial, distal fluvial/playa, and minor lacustrine environments. About 1,000 feet (305 m) thick.

Moenave Formation

Jm **Moenave Formation, undivided** – Springdale, Whitmore Point, and Dinosaur Canyon strata caught between splays of the Taylor Creek thrust. Undivided due to extensive fracturing and deformation and generally poor exposures. Also used in cross section.

Jm(s) **Slide blocks of Moenave Formation, undivided** – Principally Springdale strata displaced but not greatly disturbed by block-slide failure on a near dip slope just south of Lee Pass and southeast of Pace Knoll.

Jms **Springdale Sandstone Member** – Medium- to very thick-bedded, pale-red, light-brown, and pale-reddish-brown, fine-grained or rarely medium-grained sandstone, with planar and low-angle cross-stratification, and minor, thin, discontinuous lenses of intraformational conglomerate and thin interbeds of moderate-reddish-brown or greenish-gray mudstone and siltstone. Forms prominent cliff. Contains locally abundant petrified and carbonized fossil plant remains. Upper contact is conformable and corresponds to a prominent break in slope, with slope-forming, thin-bedded, reddish-brown, fine-grained silty sandstone above and cliff-forming, very thick-bedded sandstone below. Deposited in braided-stream and minor flood-plain environments. About 100 to 140 feet (30-43 m) thick.

Jmw **Whitmore Point Member** – Noted for its pale-red-purple, greenish-gray, and blackish-red mudstone and claystone, although upper part includes several Springdale-like sandstone beds, and lower part contains brown sandstones similar to those of the Dinosaur Canyon Member. A single dolomitic limestone bed about 6 to 12 inches (0.15-0.3 m) thick marks the base of the member; this bed is very light gray to yellowish gray, bioturbated, and locally contains small reddish-brown chert blebs, algal structures, and rare fossil fish scales of *Semionotus kanabensi.* A thin gritstone bed is locally present near the middle of the member. Weathers to poorly exposed, locally brightly colored slopes. Upper contact is conformable and gradational, although local channeling and mudstone rip-up clasts are present at the contact.

Deposited in flood-plain and lacustrine environments. About 70 to 110 feet (21-34 m) thick.

Jmd **Dinosaur Canyon Member** – Interbedded, generally thin-bedded, moderate-reddish-brown to moderate-reddish-orange, very fine- to fine-grained sandstone, very fine-grained silty sandstone, and lesser siltstone and mudstone with planar, low-angle, and ripple cross-stratification. Basal part includes a single bed of reddish-brown, very fine-grained silty sandstone several tens of feet thick. Forms ledgy slopes. Upper contact is conformable and gradational and corresponds to the base of a thin dolomite bed and the top of a white to greenish-gray sandstone bed that is 1 to 10 feet (0.3-3 m) thick. Deposited in river-channel and flood-plain environments. About 250 feet (76 m) thick.

unconformity (J-0)

TRIASSIC

Chinle Formation

TRc Chinle Formation, undivided – shown on cross section only.

TRcp **Petrified Forest Member** – Varicolored, typically gray to purple, bentonitic mudstone, claystone, siltstone, lesser sandstone and pebbly sandstone, and minor chert and nodular limestone; lowermost part locally contains light-gray, fine- to medium-grained sandstone with abundant petrified wood and cobble- to small boulder-size, "cannonball-like" sandstone concretions. Middle part of member marked by a distinctive, thick-bedded, white sandstone and pebbly sandstone. Mudstones weather to a "popcorn" surface and cause foundation

problems. Typically poorly exposed and commonly forms slumps. Contains petrified wood, especially in sandstone beds. Upper contact corresponds to the first appearance of reddish-brown, non-bentonitic siltstone and fine-grained sandstone, below which lies brightly colored swelling mudstones with abundant nodular limestone. Deposited in a variety of fluvial, flood-plain, and lacustrine environments. About 400 to 500 feet (122-152 m) thick.

TRcs **Shinarump Conglomerate Member** – Laterally and vertically variable, cliff-forming, pale- to dark-yellowish-orange, fine- to very coarse-grained sandstone, pebbly sandstone, and minor pebbly conglomerate; clasts are subrounded quartz, quartzite, and chert. Mostly thick to very thick-bedded with both planar and low-angle cross-stratification, although thin, platy beds with ripple cross-stratification occur locally. Locally heavily stained by iron-manganese oxides, forming "picture stone." Contains poorly preserved petrified wood and plant fragments, commonly replaced in part by iron-manganese oxides. Forms a prominent east-dipping cuesta. Upper contact corresponds to a prominent break in slope, with resistant sandstone and pebbly sandstone below and, generally, brightly colored mudstone above. Variable thickness from about 110 to 180 feet (35-55 m), probably due to paleotopography and deposition in braided-stream channels.

unconformity (TR-3)

Moenkopi Formation

TRm **Moenkopi Formation, undivided** – West-dipping, fault-bounded blocks of lower, middle, or upper red strata along the Hurricane fault. Also used on cross section.

TRmu **Upper red member** – Interbedded, mostly thin- to medium-bedded, moderate-reddish-orange to moderate-reddish-brown siltstone, mudstone, and very fine- to fine-grained sandstone with planar, low-angle, and ripple cross-stratification; upper part includes two prominent sandstone ledges. Upper, unconformable contact is sharp and shows minor channeling at the base of the Shinarump Conglomerate. Deposited in tidal-flat and coastal-plain environments. About 250 feet (76 m) thick.

TRms **Shnabkaib Member** – Forms "bacon striped," ledgy slopes of laminated to thin-bedded, gypsiferous, pale-red to moderate-reddish-brown mudstone and siltstone, resistant, white to greenish-gray gypsum and lesser thin, laminated, light-gray dolomite beds. Gypsum present as laterally continuous, very thick beds; finely laminated, commonly silty or muddy beds; and nodular intervals that range from less than one inch to about 9 feet (0.01-3 m) thick; gypsum also present as secondary cavity fillings and cross-cutting veins. Weathers to soft, punky, gypsiferous soils. Upper, conformable and gradational contact corresponds to the top of the highest thick gypsum bed. Deposited in a variety of supratidal, intertidal, and subtidal environments on a broad, coastal shelf of very low relief. About 450 feet (137 m) thick.

TRmm **Middle red member** – Interbedded, laminated to thin-bedded, moderate-reddish-brown to moderate-reddish-orange siltstone, mudstone, and very fine-grained sandstone; white to greenish-gray gypsum beds and veins are common, especially in the lower part of the member. Upper, conformable and gradational contact corresponds to the base of the first thick gypsum bed. Deposited in a tidal-flat environment. About 550 feet (168 m) thick.

TRmv **Virgin Limestone Member** – Very pale-orange to yellowish-gray, finely crystalline limestone and silty limestone; light-gray to light-olive-gray, coarsely crystalline fossiliferous limestone with locally abundant circular and five-sided crinoid columnals, gastropods, and brachiopods; and siltstone and mudstone. Contains three prominent limestone ledges separated by poorly exposed mudstone slopes; forms prominent, east-dipping questa east of the Hurricane Cliffs. Upper, conformable contact corresponds to the top of the uppermost Virgin limestone bed. Deposited in a shallow-marine environment. About 200 feet (61 m) thick.

TRml **Lower red member** – Interbedded, laminated to thin-bedded, moderate-reddish-brown mudstone and siltstone with local, thin, laminated, light-olive-gray gypsum beds and veinlets. Upper, unconformable contact corresponds to the base of the lowermost Virgin limestone bed. Deposited in a tidal-flat environment. About 280 feet (85 m) thick.

TRmt **Timpoweap Member** – Lower part consists of light-brown weathering, light-gray to grayish-orange, thin- to thick-bedded, planar-bedded limestone and cherty limestone; upper part consists of grayish-orange, thin- to thick-bedded, planar-bedded, very fine- grained sandstone, siltstone, and mudstone. Both parts contain locally abundant, but poorly preserved, bivalve fossils. Chert is present as disseminated blebs and grains, thus giving limestones a very rough weathering appearance. Caps the Hurricane Cliffs where it forms low cliffs and ledges and a gently undulating surface on top of the Permian-Triassic unconformity. Upper contact is conformable and gradational and corresponds to a change from yellowish-brown, fine-grained

sandstone, siltstone, and minor limestone below to reddish-brown siltstone and mudstone above. Deposited in a shallow-marine environment. Varies from about 60 to 120 feet (18-37 m) thick.

TRmr **Rock Canyon Conglomerate Member** – Consists of two main rock types: a pebble to cobble, clast-supported, channel-form conglomerate with subrounded to rounded chert and minor limestone clasts derived from Harrisburg strata, which was deposited in paleovalleys and is 0 to about 90 feet (0-27 m) thick; and a widespread, but thin, breccia 0 to 5 feet (0-1.5 m) thick, which probably formed as a regolith deposit on Harrisburg strata. Conformably and gradationally overlain by limestone of the Timpoweap Member. Only the conglomeratic facies is mapped separately.

unconformity (TR-1)

PERMIAN

Kaibab Formation

Pk Kaibab Formation, undivided – shown in cross section only.

Pkh **Harrisburg Member** – Laterally variable, slope- and ledge-forming, thin- to thick-bedded limestone and dolomite with common white nodular and ribbon chert; contains minor intraformational breccias and intraformational pebbly conglomerates. Unconformably overlain by Rock Canyon Conglomerate river-channel and breccia deposits. Deposited in a

complex sequence of shallow-marine and sabkha environments. About 100 feet (30 m) thick.

Pkf, Pkf?

Fossil Mountain Member – Light-gray, thick- to very thick-bedded, planar-bedded, fossiliferous limestone and cherty limestone; fossils are well-preserved brachiopods, bryozoans, and disarticulated crinoids. Forms prominent "black-banded" cliff due to abundant reddish-brown, brown, and black nodular and ribbon chert. Upper contact is conformable and corresponds to a sharp break in slope. Query indicates uncertain identification due to structural complications. Deposited in a shallow-marine environment. About 200 to 250 feet (61-76 m) thick.

Toroweap Formation

Pt Toroweap Formation, undivided – shown in cross section only.

Ptw, Ptw?

Woods Ranch Member – Interbedded, slope- and ledge-forming, yellowish-gray to light-gray, laminated to thin-bedded cherty limestone, cherty dolomite, and calcareous siltstone; contains minor gypsiferous mudstone and collapse breccia. Contact with Fossil Mountain strata is conformable and corresponds to a break in slope at the first appearance of black-banded, cliff-forming limestone. Deposited in a complex sequence of shallow-marine, supratidal, and sabkha environments. Query indicates uncertain identification due to structural complications. Varies from 115 to 145 feet (35-44 m) thick.

Ptb **Brady Canyon Member** – Light- to medium-gray, medium- to coarse-grained, thick- to very thick-bedded, planar-bedded, fossiliferous limestone and cherty limestone; fossils are broken brachiopods, bryozoans, and crinoids; black to reddish-brown ribbon chert and irregular chert nodules locally make up to 30 to 40 percent of the rock. Upper, unconformable contact corresponds to a break in slope. Deposited in a shallow-marine environment. Typically forms prominent cliff, but only upper 150 feet (46 m) is exposed near the base of the Hurricane Cliffs; the member is 220 to 255 feet (67-78 m) thick to the southwest in the Pintura quadrangle (Hurlow and Biek, in preparation).

Subsurface Units

Pq Queantoweap Sandstone – shown in cross section only.

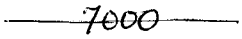
Pzu Paleozoic (pre-Queantoweap), undivided – shown in cross section only.

Map Symbols

Contact, dashed where approximately located

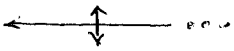

Normal fault, dashed where approximately located, dotted where concealed; bar and ball on down-thrown side


Thrust fault, dotted where concealed; teeth on upper plate

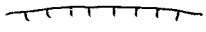


Structure contour on top of Navajo Sandstone; interval 100 feet

Major joint


Anticline, dotted where concealed; arrow shows plunge direction


Syncline, dotted where concealed; arrow shows plunge direction


Landslide or slump scarp, teeth on down-dropped side

Strike and dip of inclined bedding


Approximate strike and dip direction of inclined bedding

Approximate strike and dip of inclined bedding determined photogrammetrically


Strike of vertical bedding

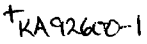

Strike of near-vertical joint


Pit - sand and gravel (no letter), cinders (c)


Prospect – uranium (u), metals (no letter)


Adit – uranium mine


Spring



Sample location and number

References

Biek, R.F., in preparation, Geologic map of the Hurricane quadrangle, Washington County, Utah: Utah Geological Survey Map, scale 1:24,000.

Biek, R.F., and Hylland, M.D., 2002, Interim geologic map of the Cogswell Point quadrangle, Washington, Kane, and Iron Counties, Utah: Utah Geological Survey Open-File Report 388, scale 1:24,000.

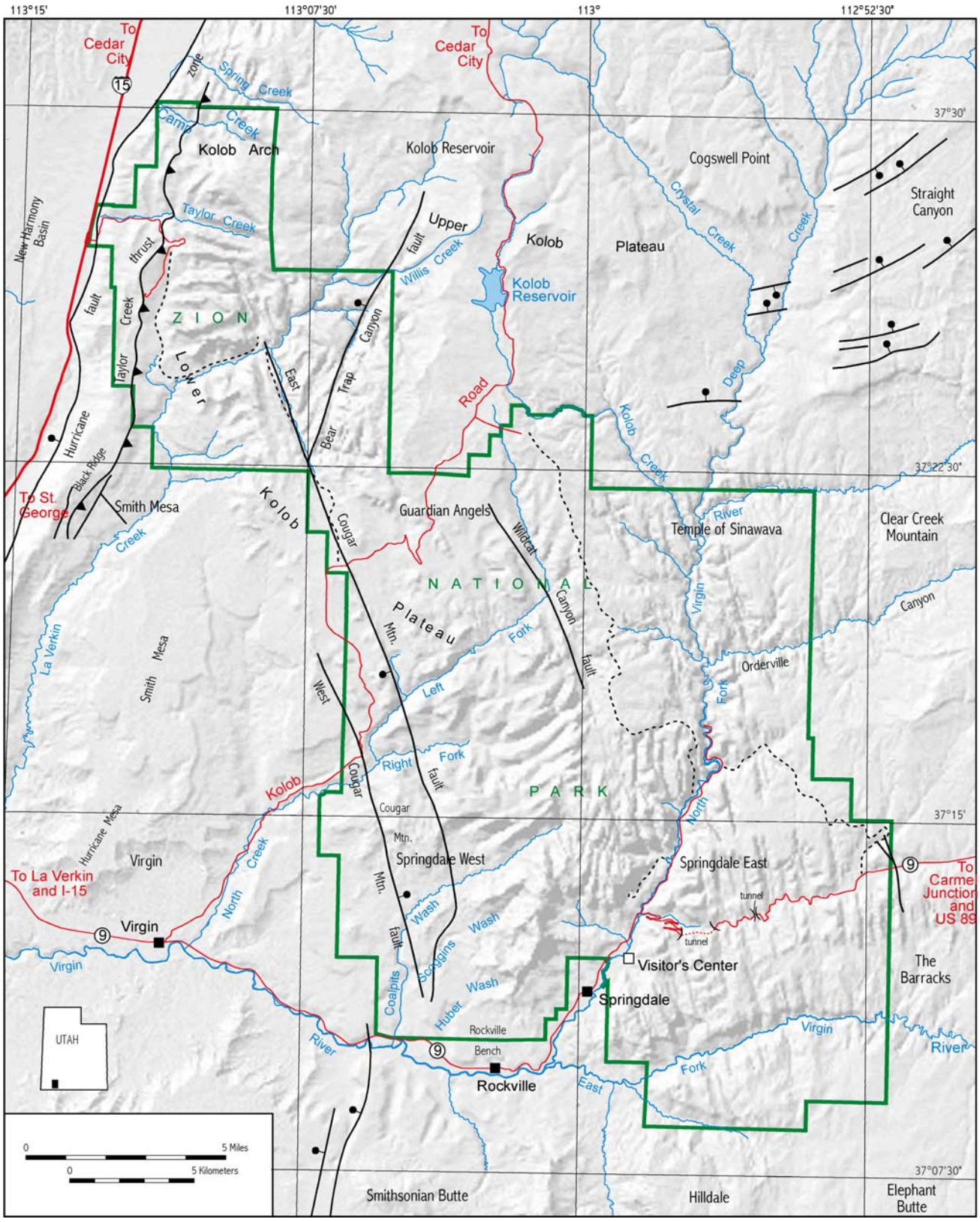
Eardley, A.J., 1966, Rates of denudation in the High Plateaus of southwestern Utah: Geological Society of America Bulletin, v. 77, p. 777-780.

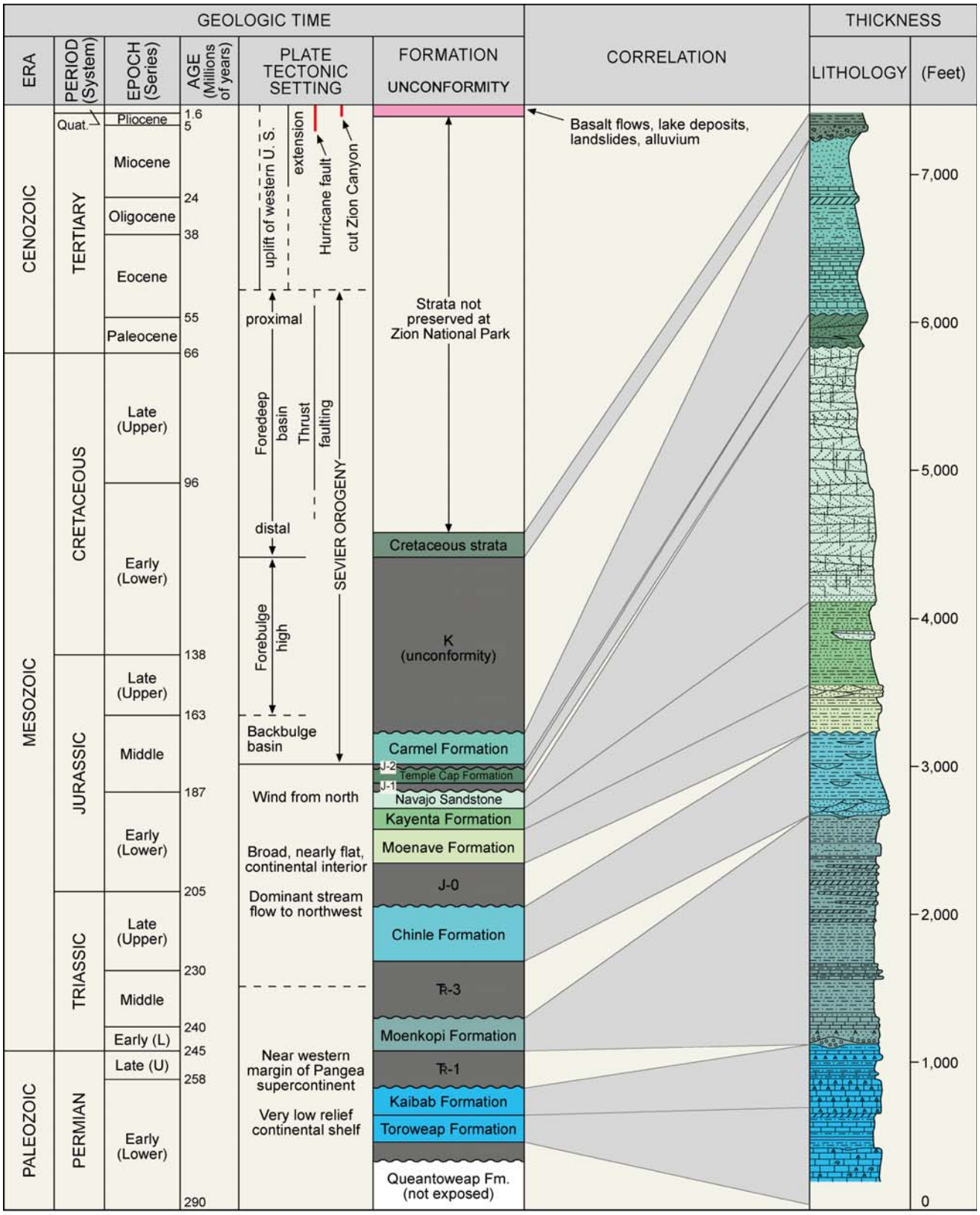
Hamilton, W.L., 1995, The sculpturing of Zion: Springdale, Utah, Zion Natural History Association, 132 p.

Hurlow, H.A., 1998, The geology of the central Virgin River basin, southwestern Utah, and its relation to ground-water conditions: Utah Geological Survey Water-Resources Bulletin 26, 53 p., 6 pl., various scales.

Hurlow, H.A., and Biek, R.F., in preparation, Geologic map of the Pintura quadrangle, Washington County, Utah: Utah Geological Survey Map, scale 1:24,000.

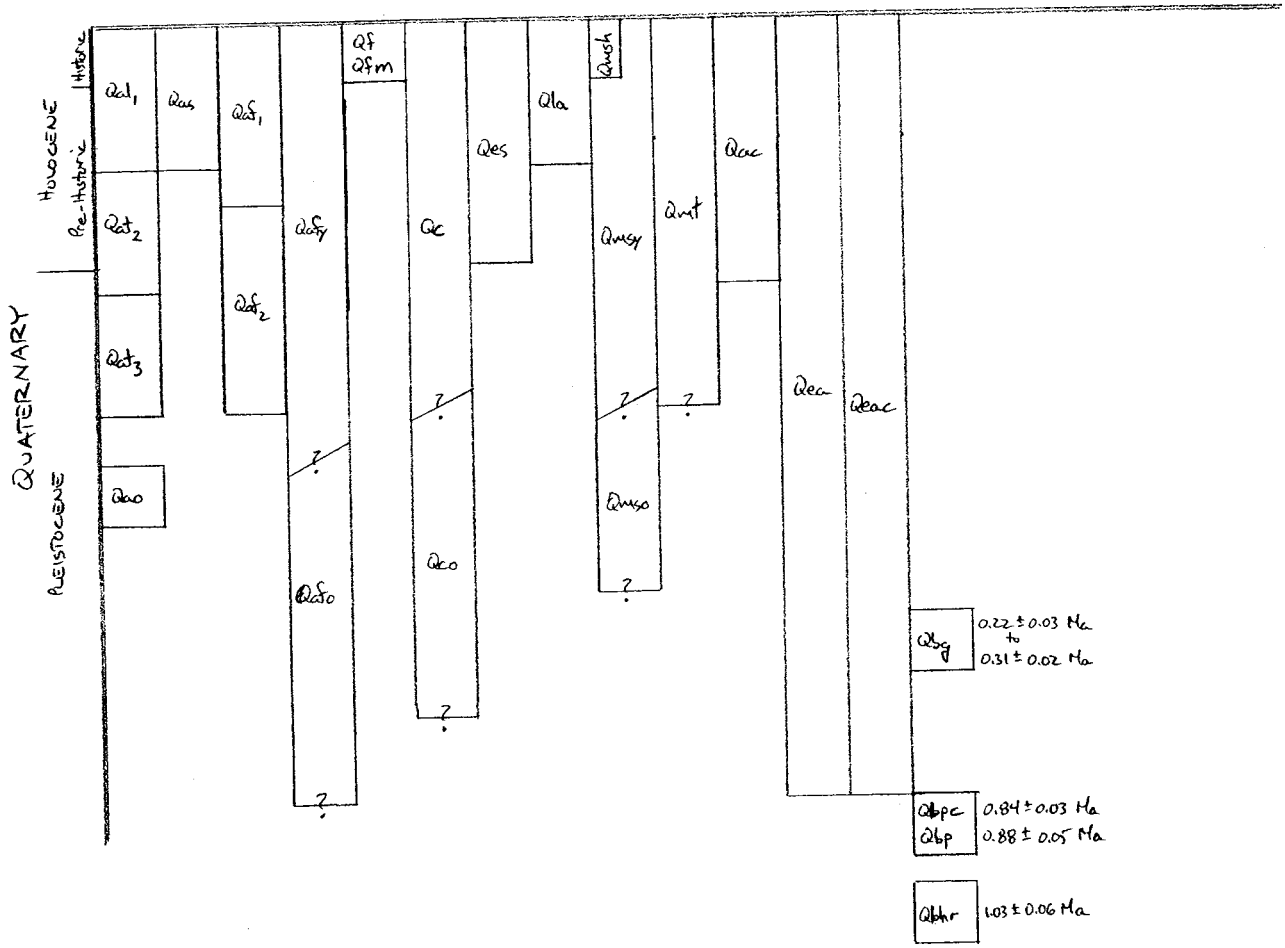
Lund, W.R., Pearthree, P.A., Amoroso, Lee, Hozik, M.J., and Hatfield, S.C., 2001, Paleoseismic investigation of earthquake hazard and long-term movement history of the Hurricane fault, southwestern Utah and northwestern Arizona – Final Technical Report: U.S. Geological Survey, National Earthquake Hazards Reduction Program, 71 p. with appendices.

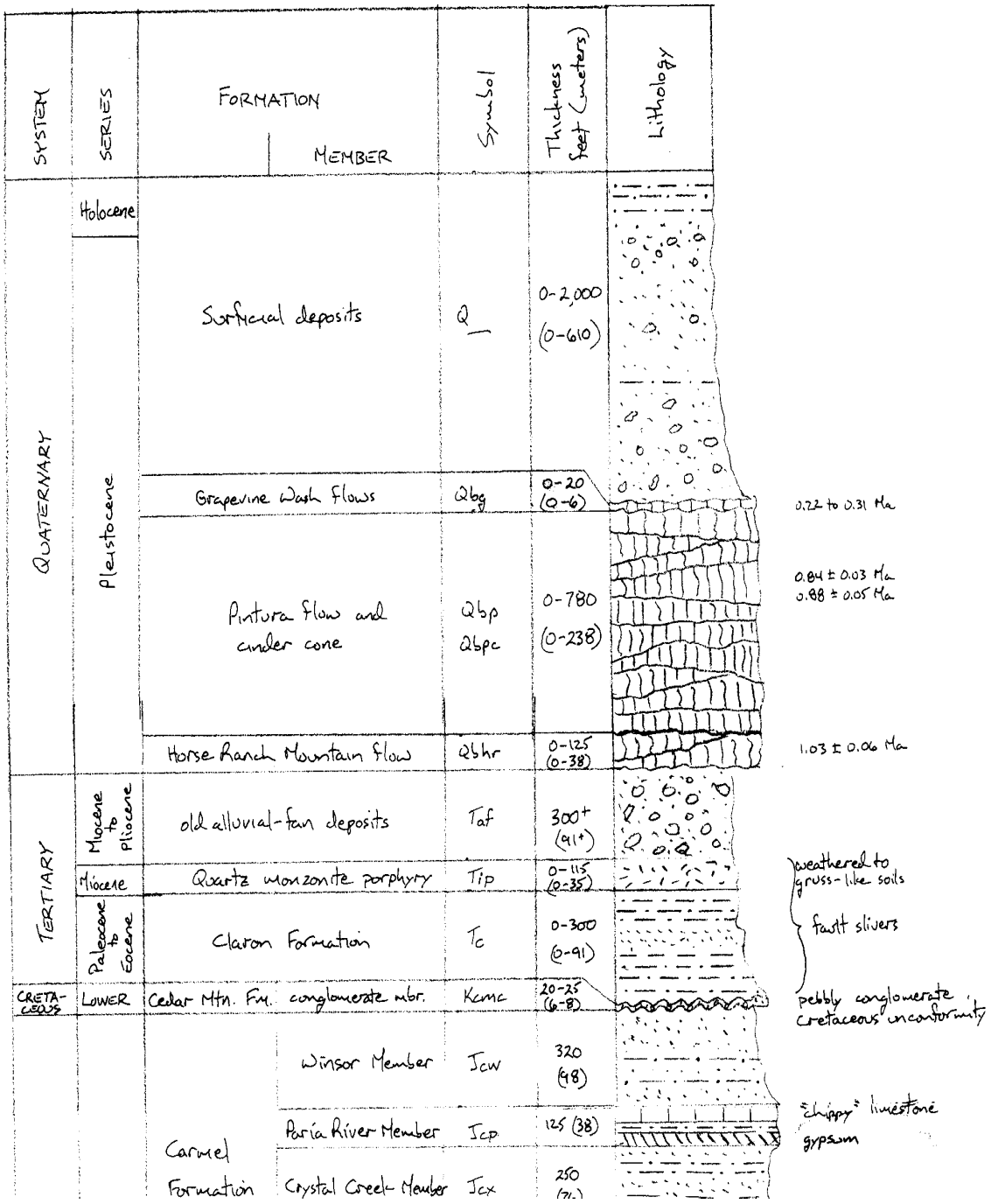

113°15'
113°07'30'
113°
112°52'30"
37°30'
37°22'30"
37°15'
37°07'30"
To Cedar City
15
Spring Creek
Camp Creek
Kolob Arch
Kolob Reservoir
Cogswell Point
Straight Canyon
Crystal Creek
Deep Creek
New Harmony Basin
Taylor Creek
thrust fault
Upper Willis Creek fault
Kolob Plateau
Kolob Reservoir
Z I O N
Lower East Trap Canyon
Bear
Road
Deep
Kolob Creek
Hurricane fault
Black Ridge
Taylor Creek
To St. George
Smith Mesa
Kolob
Cougar
Guardian Angels
Wildcat Canyon fault
Temple of Sinawava
Clear Creek Mountain
Virgin River
N A T I O N A L
Plateau Mtn.
Fork
Canyon
La Verkin Creek
Smith Mesa
West Fork Left Fork
Orderville
Canyon
Right Fork
Kolob Cougar Mtn. fault
P A R K
North Fork
Hurricane Mesa
Virgin
To La Verkin and I-15
Springdale West
Springdale East
To Carmel Junction and US 89
tunnel
tunnel
North Creek
Virgin
Wash
Scoggins Wash
Visitor's Center
The Barracks
Springdale
Coalpits Wash
Huber Wash
Rockville
Bench
Rockville
Virgin River
Virgin River
East Fork
UTAH
0
5 Miles
0
5 Kilometers
Smithsonian Butte
Hilldale
Elephant Butte

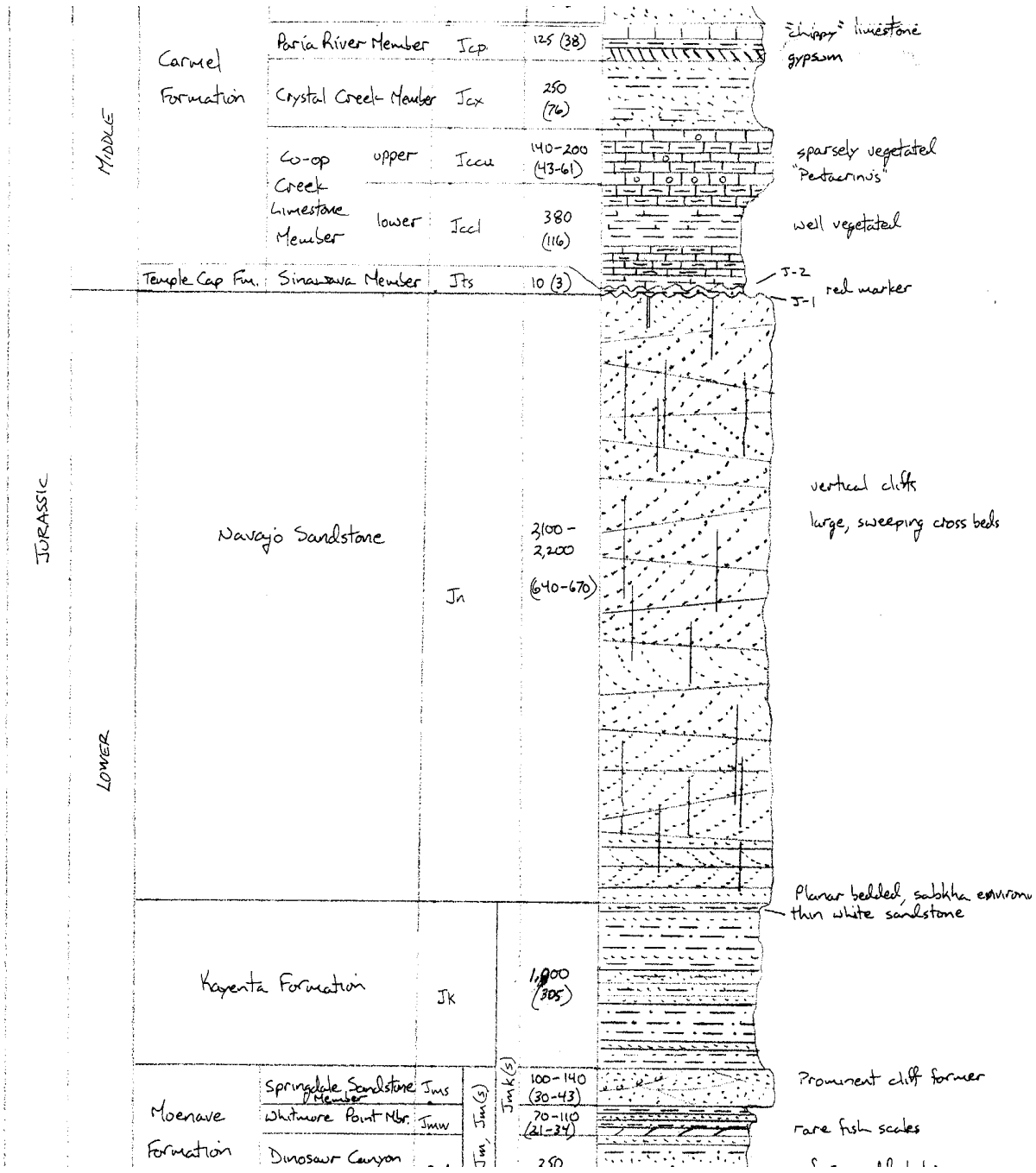


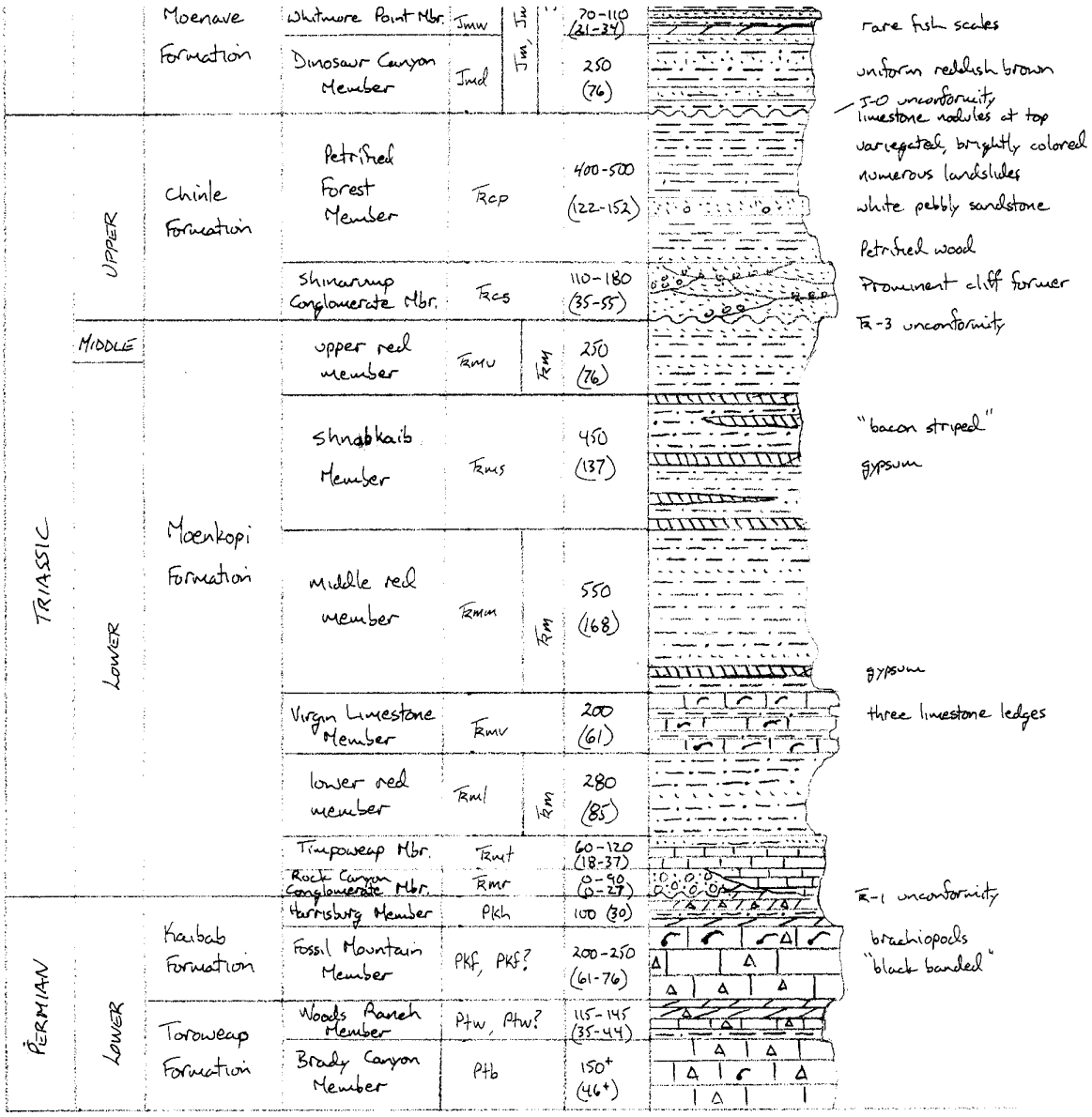
Relationship between age and thickness of rocks exposed in Zion National Park.

CORRELATION OF SURFICIAL MAP UNITS - KOLOB ARCH QUADRANGLE

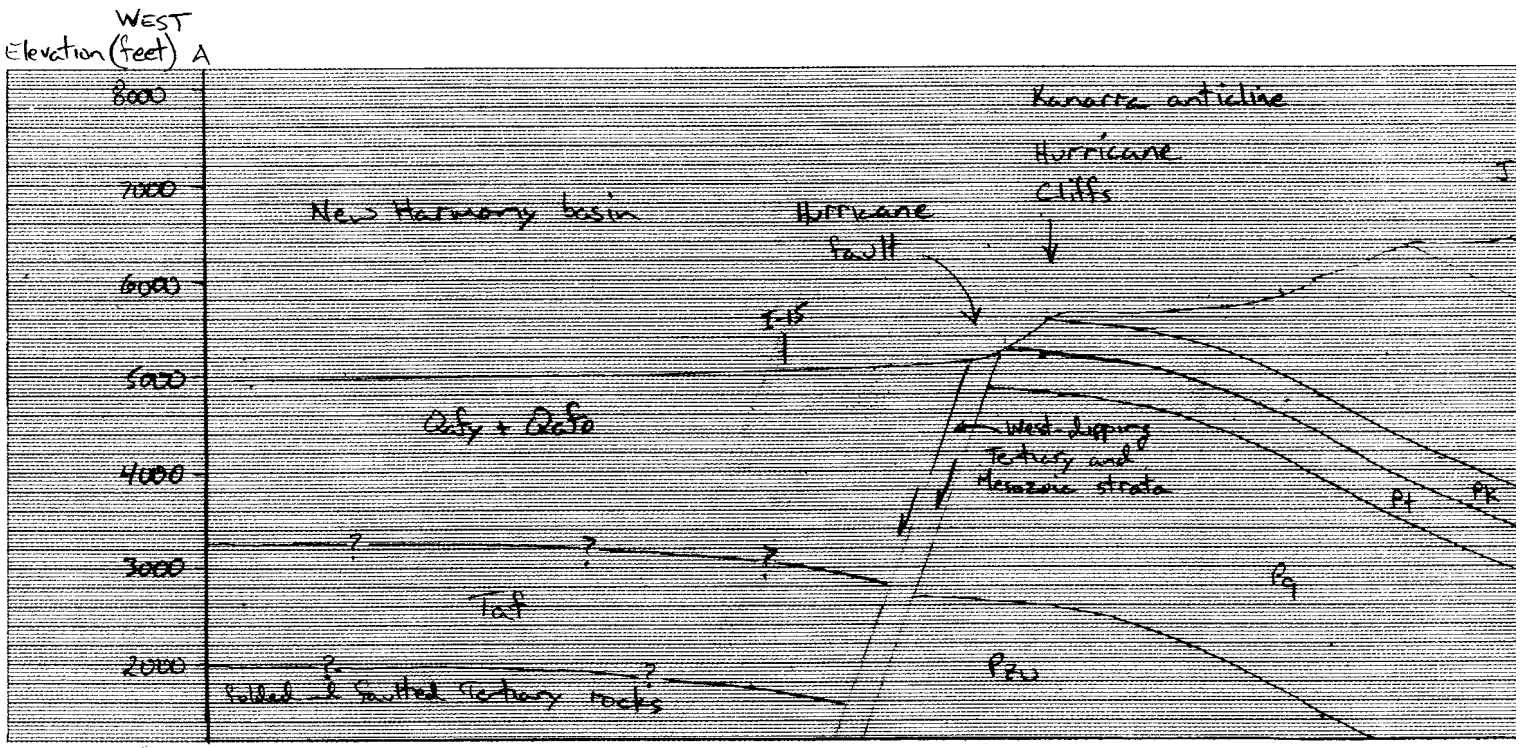


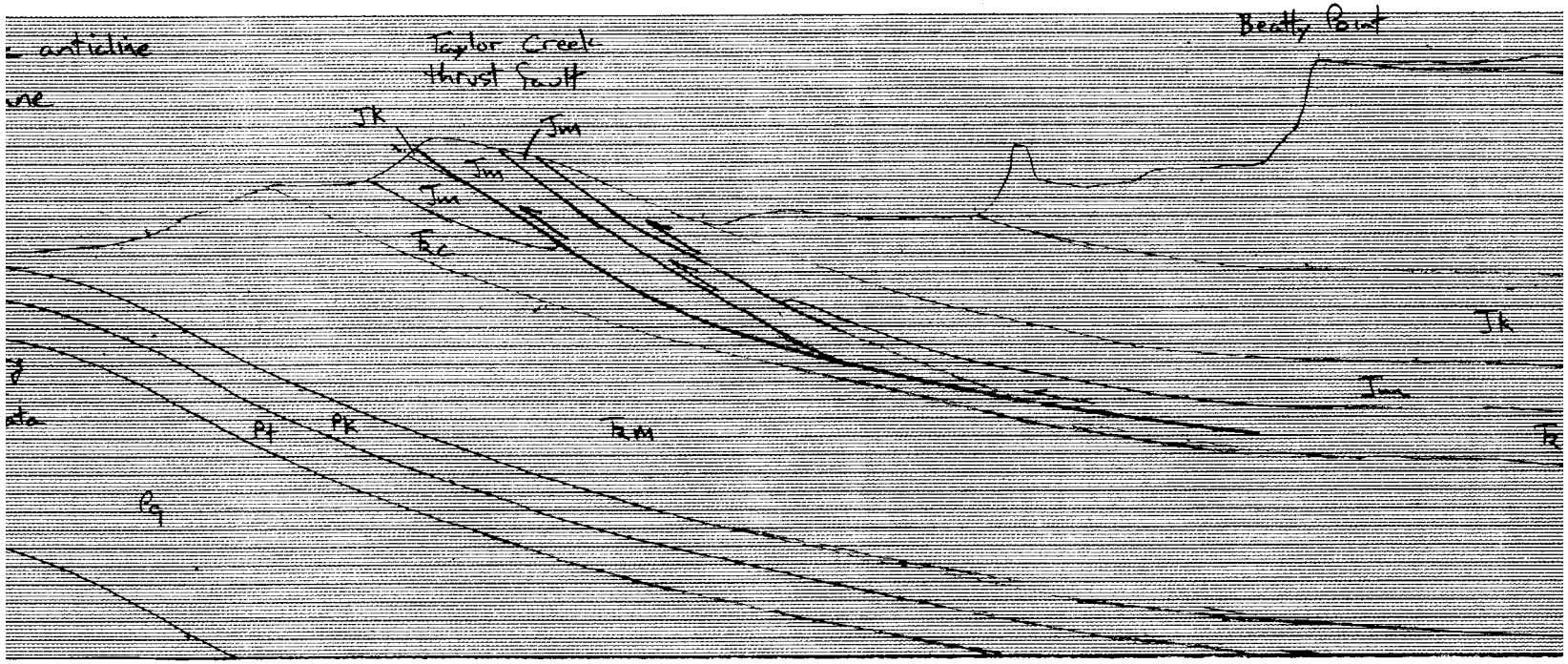

SYSTEM
SERIES
FORMATION
MEMBER
Symbol
Thickness feet (meters)
Lithology
QUATERNARY
Holocene
Pleistocene
Surficial deposits
Q
0-2,000
(0-610)
Grapevine Wash flows
Qbg
0-20
(0-6)
0.22 to 0.31 Ma
Pintura flow and cinder cone
Qbp
Qbpc
0-780
(0-238)
0.84 ± 0.03 Ma
0.88 ± 0.05 Ma
Horse Ranch Mountain flow
Qbhr
0-125
(0-38)
1.03 ± 0.06 Ma
TERTIARY
Miocene & Pliocene
old alluvial-fan deposits
Taf
300+
(91+)
Miocene
Quartz monzonite porphyry
Tip
0-115
(0-35)
weathered to gruss-like soils
Paleocene to Eocene
Claron Formation
Tc
0-300
(0-91)
fault slivers
CRETACEOUS
LOWER
Cedar Mtn. Fm. conglomerate mbr.
Kcmc
20-25
(6-8)
pebbly conglomerate
Cretaceous unconformity
Carmel Formation
Winsor Member
Jcw
320
(98)
Paria River Member
Jcp
125 (38)
"chippy" limestone
gypsum
Crystal Creek Member
Jcx
250
(?)

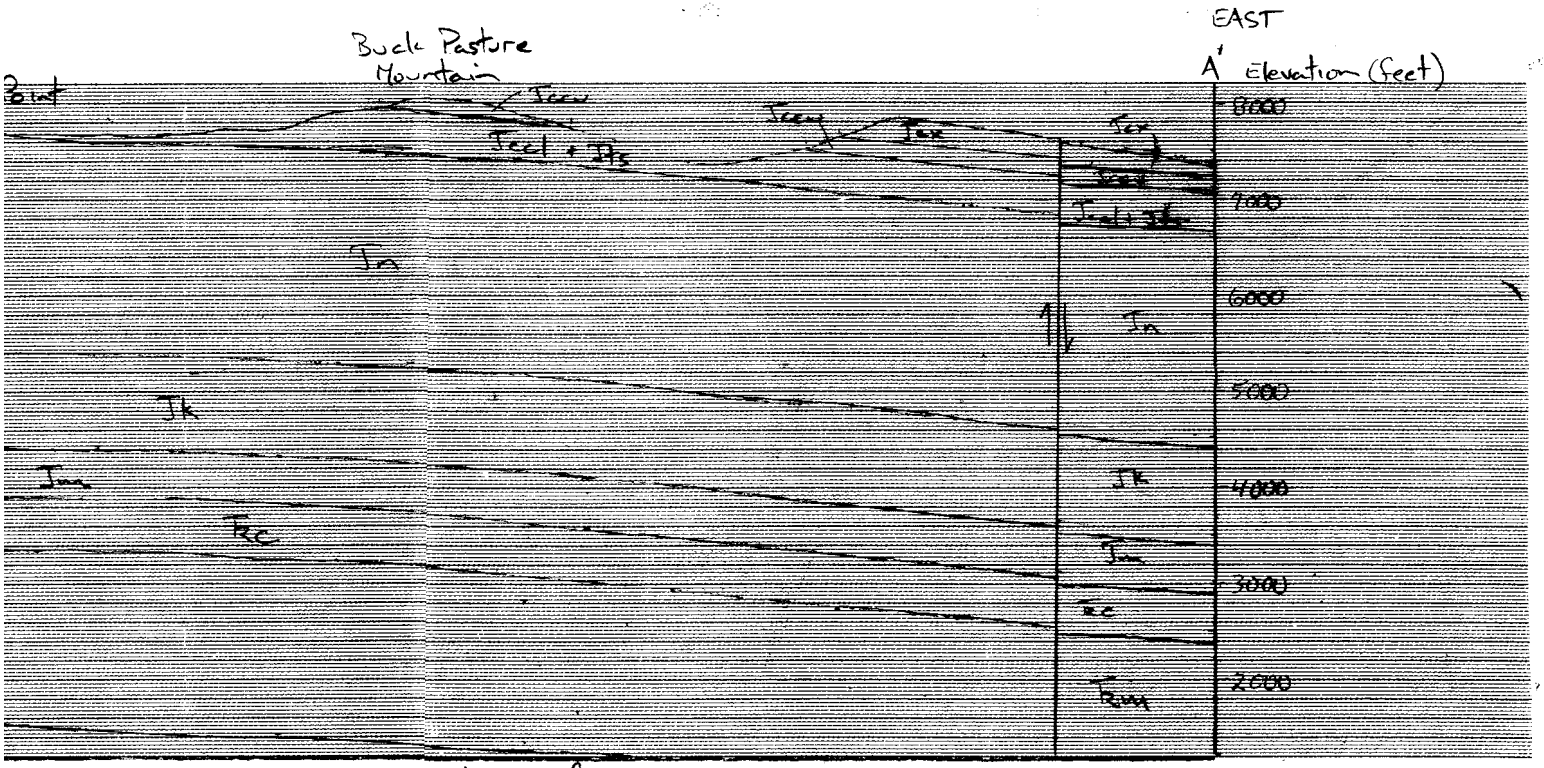

JURASSIC
MIDDLE
LOWER
Carmel Formation
Paria River Member
Jcp
125 (38)
"chippy" limestone
gypsum
Crystal Creek Member
Jcx
250
(76)
Co-op Creek Limestone Member
upper
Jccu
140-200
(43-61)
sparsely vegetated
"Pentacrinus"
lower
Jccl
380
(116)
well vegetated
Temple Cap Fm.
Sinawava Member
Jts
10 (3)
J-2
J-1
red marker
Navajo Sandstone
Jn
3100 -
2,200
(640-670)
vertical cliffs
large, sweeping cross beds
Planar bedded, sabkha environ
thin white sandstone
Kayenta Formation
Jk
1,000
(305)
Moenave Formation
Springdale Sandstone Member
Jms
Jmw(s)
Jmk(s)
100-140
(30-43)
Prominent cliff former
Whitmore Point Mbr.
Jmw
70-110
(21-34)
rare fish scales
Dinosaur Canyon
Jmd
250



KOLOB ARCH QUADRANGLE


WEST
Elevation (feet)
A
8000
7000
6000
5000
4000
3000
2000
New Harmony basin
Hurricane fault
Kanarra anticline
Hurricane cliffs
T-15
Qafy + Qafo
West-dipping Tertiary and Mesozoic strata
Taf
?
Folded & faulted Tertiary rocks
PK
P1
Pm
Pzu

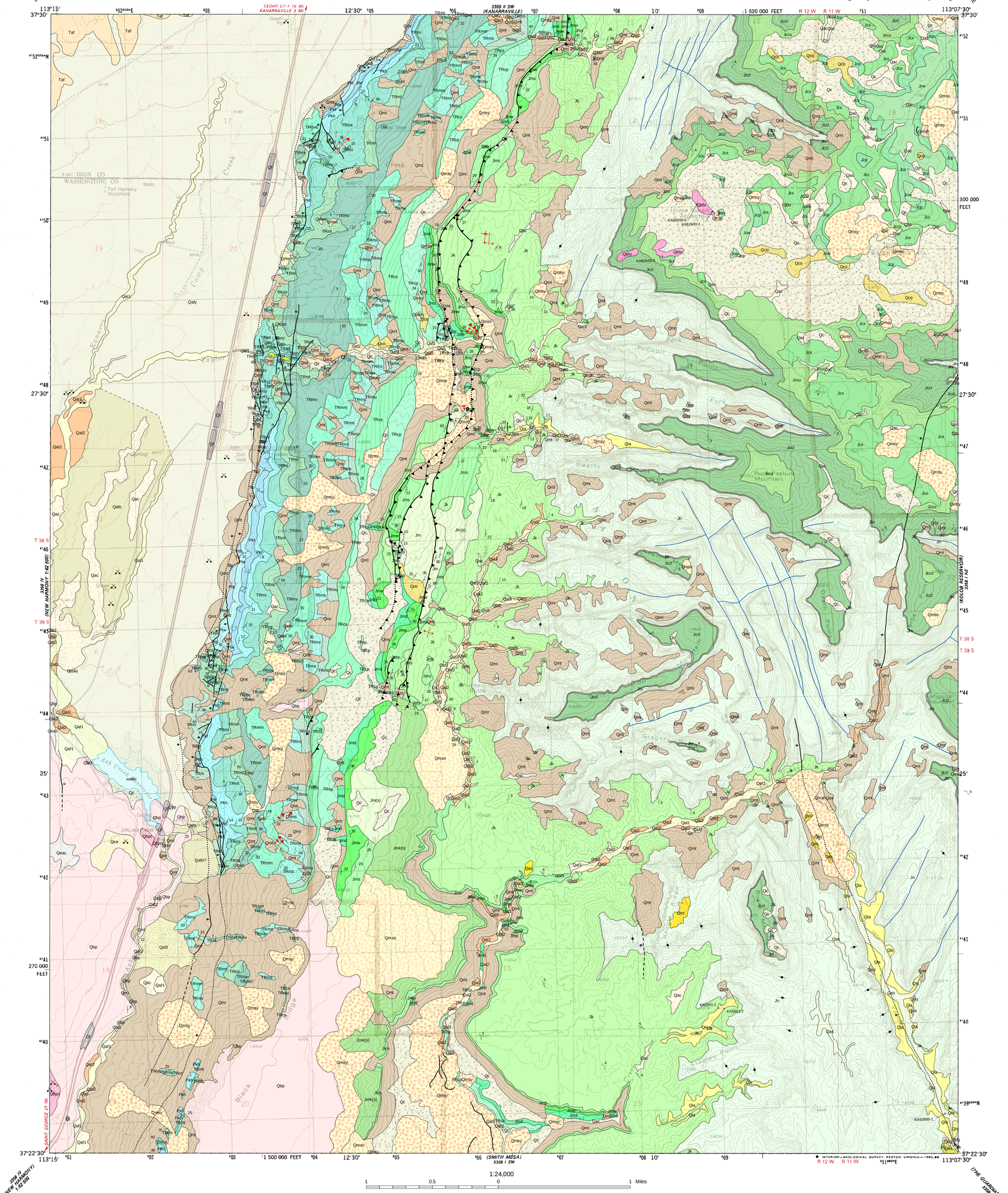

anticline
ine
Taylor Creek
thrust fault
Beatty Point
JK
Jm
Jm
Jm
Kc
Jk
Jm
Kc
Pf
Pk
Kcm
Qg



Thin surficial deposits not shown

UTAH GEOLOGICAL SURVEY
a division of the
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with the
NATIONAL PARKS SERVICE

Plate 1
Utah Geological Survey Open-File Report 386
Interim Geologic Map of the Kolob Arch Quadrangle



Interim Geologic Map of the Kolob Arch Quadrangle, Washington and Iron Counties, Utah

by
Robert F. Biek

2002